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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G01K 1/16, 13/02

A1

(11) International Publication Number: WO 97/01746

(43) International Publication Date: 16 January 1997 (16.01.97)

(21) International Application Number: PCT/DK96/00281

(22) International Filing Date: 25 June 1996 (25.06.96)

(30) Priority Data:
0736/95 26 June 1995 (26.06.95) DK

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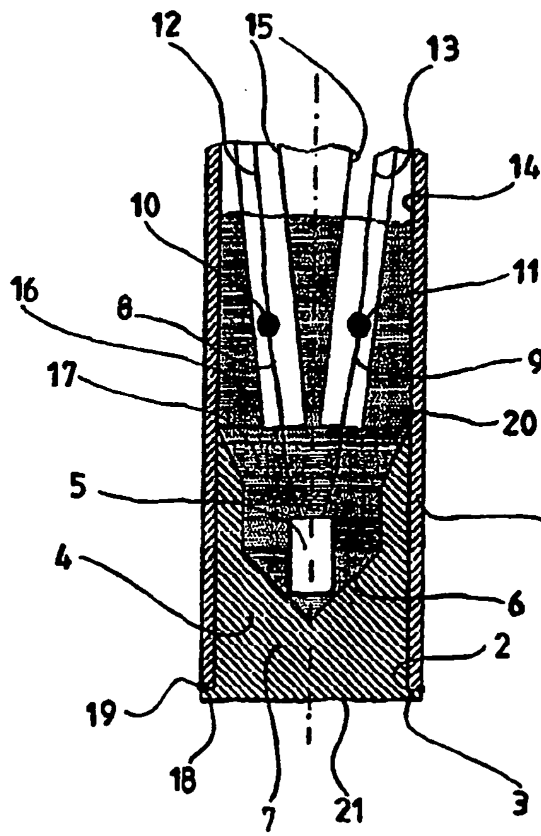
(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: A TEMPERATURE SENSOR

(57) Abstract

A temperature detector (5), such as a resistance temperature detector (RTD) or a thermocouple, is embedded in a body (16) of a heat resistant ceramic cement inside a tubular member (4), the RTD being in physical contact with a conical depression (6) in a plug element (7) of the tubular member (4). The tubular member (4) is fitted into one end of another tubular member (1) with a flange (18) abutting and welded to the annular edge (3) of an aperture (2) of the tubular member (1). The surface (21) of the plug element is exposed to direct contact with a fluid surrounding the shown portion of the tubular member (1) constituting the sensor casing of a temperature sensor for monitoring the temperature of the fluid.



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A TEMPERATURE SENSOR

This invention relates to a temperature sensor for use in monitoring the temperature in a fluid and a method for producing said temperature sensor.

Temperature sensors for monitoring the temperature in a fluid are known where a casing mounted on a wall of a receptacle or a conduit encloses a temperature detector connected by conductive leads extending through the casing to separate measuring equipment or the like. The purpose of the casing is to locate the detector in the fluid in the receptacle or the conduit and to protect the detector from potentially damaging contact with the fluid therein.

In the most well known type of such sensors a tubular member having a closed end and an open end constitutes the casing, the detector being arranged adjacent to the closed end. The detector is fixed in position in the closed end by means of a heat conductive high temperature adhesive or for instance heat conductive aluminium oxide powder, and the conductive leads are fixed and supported in the casing by means of for instance heat conductive aluminium oxide powder.

The detector is positioned in the closed end by manually inserting it from the open end by means of the conductive leads whereafter the adhesive and/or the powder are manually introduced in the tubular member. This procedure is quite time-consuming and therefore relatively expensive, and the position of the detector in the closed end of the tubular member is not well-defined, giving rise to significant variations in the temperature sensing characteristics of the individual sensors.

The filling process for both the adhesive and the powder also entails lack of control as to whether the space surrounding the detector and the leads is completely filled. This often results in voids in the adhesive or powder giving rise to

deficient heat transfer from the fluid to the detector with consequent increase in the reaction time to variations in temperature. Furthermore, voids in the powder surrounding the conductive leads may give rise to fatigue failure of same as a result of the vibrations to which the sensor often is subjected.

Finally, the reaction time of the detector is dependent on the heat transfer rate through the wall of the tubular member and the adhesive and/or the powder. This reaction time is often very critical for the applications of the sensor, and therefore it is important that the reaction time be as short as possible.

It is the object of the invention to provide a temperature sensor for monitoring the temperature in a fluid where the disadvantages described above have been overcome or ameliorated and wherein the reaction time of the sensor to temperature variations in the fluid has been substantially reduced.

This object is obtained according to the invention by the sensor comprising a sensor casing having a first and a second aperture mutually interconnected by a passage, a temperature detector assembly inserted in the first aperture, conductive leads electrically connected to the assembly and extending through the passage to the second aperture, the temperature detector assembly comprising a detector casing of a thermally conductive metal and a temperature detector, such as a resistance temperature detector or a thermocouple, accommodated in said detector casing, the assembly being arranged such in the first aperture that a substantial portion of the detector casing in use is exposed to direct contact with the fluid.

Hereby it is obtained that the detector is arranged in a separate detector casing enabling much better control of the fixation of the detector in same, thereby achieving uniformity as regards performance and greater precision in measuring the temperature of the fluid. A substantial proportion of the

total heat transmission to and from the detector from and to the fluid takes place through the said substantial portion of the detector casing thereby enabling an increase in the rate of heat transmission and thereby a reduction of the reaction time.

The detector may be fixed in the detector casing in many ways such as mechanically by friction, clamping, retaining means and so on. However, the detector is preferably at least partly embedded in a high temperature adhesive at least partly filling the detector casing. This is a particularly simple and inexpensive fixation of the detector in the detector casing and may be carried out with no risk of voids as the access to the detector casing for introducing the adhesive may be very simple and reliable.

Advantageously, the adhesive may be a heat conductive, electrically insulating ceramic cement. Hereby, the heat transfer to the detector is enhanced and the risk of disturbing the electrical signals from the detector is eliminated. This cement may advantageously be Omegabond "600" ® manufactured by Omega Engineering Inc. of Stamford, USA.

According to the invention the detector may be in thermally conductive communication with a region of the detector casing comprised by or adjacent to said substantial portion thereof. Hereby a better heat transmission to and from the detector is obtained, the rate of transmission being well-defined and uniform from sensor to sensor.

Advantageously, the detector may be in physical contact with a region of said substantial portion of the detector casing.

A particularly simple and inexpensive embodiment is obtained according to the invention by the sensor casing comprising a first tubular member, having the first and second aperture, respectively, at opposed ends thereof.

Advantageously the detector casing may comprise a second tubular member having one end open and the other end closed by a plug element, at least a part of the plug element being at least a part of the substantial portion of the detector casing for exposure to direct contact with the fluid.

The sensor casing and the detector casing may comprise means for sealing the detector casing relative to the sensor casing such that the open end of the second tubular member in use is not exposed to the fluid, and the plug element may have an annular region with larger diameter than the diameter of the second tubular element such that an annular flange is formed around the closed end of the second tubular member.

A particularly simple and reliable embodiment is obtained by the outer diameter of the annular region of the plug element being substantially equal to the outer diameter of the first tubular member and the annular flange being welded to the first tubular member for establishing a fluid-tight seal therebetween.

The conductive leads extending from the detector are susceptible to damage by vibrations and a particularly simple and reliable embodiment having a reliable fixation of the leads relative to the detector is achieved by the high temperature adhesive substantially filling the detector casing and enveloping the first stretch of the conductive leads from the detector.

So as to avoid fatigue failure of the adhesive in the region adjacent to the edge of the open end of the second tubular member the edge region of the open end may taper to a substantially sharp edge.

The reaction time of the detector depends directly on the rate of heat transmission to and from the detector from and to the fluid, and therefore heat transmission to and from the detector from all adjacent portions of the sensor should be

facilitated to as large a degree as possible. It is therefore advantageous that the outer diameter of the second tubular member is substantially equal to the inner diameter of the first tubular member such that a tight fit may be established between the second and first tubular members.

In such case it is also advantageous that the adhesive enveloping said first stretch forms a cylindrical portion having the same outer diameter as the second tubular member.

A particularly simple and reliable embodiment, wherein the localization of the detector relative to the detector casing, for instance in a central position, is achieved by the plug element comprising guiding means to guide the detector into a certain position relative to the plug element and maintaining means to maintain the detector in said position.

Advantageously, the guiding means and maintaining means may be constituted by a conical depression in the surface of the plug element facing the open end of the second tubular member, the conical depression receiving the detector adjacent the apex thereof.

This invention also relates to a method of producing a temperature sensor for use in monitoring the temperature in a fluid, and according to the invention the method comprises the steps of

- providing a sensor casing having a first and a second aperture mutually interconnected by a passage,

- providing a temperature detector having conductive leads extending therefrom,

- providing a detector casing of a thermally conductive metal,

- locating the detector in a predetermined, fixed position within the detector casing by means of a heat conductive high temperature adhesive,

- inserting the conductive leads through the passage in the sensor casing from the second aperture thereof to the first aperture thereof,

- pulling the detector casing into the second aperture by means of the conductive leads to a sensing position such that a substantial portion of the detector casing is exposed to the exterior and thus in use will be exposed to direct contact with the fluid,

- fixing the detector casing in the sensing position, and

- sealing the detector casing relative to the sensor casing such that the passage, the detector and the conductive leads in use will not be exposed to the fluid.

Hereby, a simple, reliable and relatively inexpensive method for producing a temperature sensor having a relatively short reaction time, uniform performance and great precision is provided.

According to the invention the method according to the invention of producing a temperature sensor for use in monitoring the temperature in a fluid comprises the steps of:

- providing a first tubular member having a first and a second aperture at opposed ends thereof, the second aperture having an annular edge,

- providing a second tubular member having one end open and the other closed by a plug element having an annular region with a diameter substantially equal to the diameter of the first tubular element, said annular region forming an annular flange,

- providing a temperature detector having conductive leads extending therefrom,

- placing the detector in a predetermined position in physical contact with the surface of the plug element facing the open end of the second tubular member,

- providing a high temperature adhesive in the second tubular member such that the detector is fixed in said position,

- inserting the conductive leads through the first tubular member from the second aperture thereof to the first aperture thereof,

- pulling the detector casing into the second aperture by means of the conductive leads to a sensing position such that the annular flange abuts the annular edge of the second aperture,

- fixing and sealing the annular flange with respect to the annular edge such that the detector and the conductive leads in use will not be exposed to the fluid.

Advantageously, the adhesive may be a heat conductive, electrically insulating ceramic cement and the annular flange may be welded to the annular edge for establishing a fluid-tight seal therebetween.

According to the invention the high temperature adhesive may be provided such that it substantially fills the second tubular member and envelops the first stretch of the conductive leads from the detector and the adhesive enveloping said first stretch may be provided such that it forms a cylindrical portion having the same outer diameter as the second tubular member.

The invention will now be explained more in detail with reference to the accompanying drawings where

Fig. 1 shows a partial view of an embodiment of a temperature sensor according to the invention, and

Fig. 2 illustrates a step in an embodiment of a method according to the invention of producing the embodiment of Fig. 1.

Referring now to Fig. 1, a tubular member 1 constituting the sensor casing extends through and is fastened to a wall of a receptacle or conduit (not shown) enclosing the fluid in question. The tubular member 1 is provided with an aperture 2 delimited by an annular edge 3 and accommodates a tubular member 4 constituting the detector casing. A resistance temperature detector (RTD) 5 is located in the tubular member 3 in physical contact with a conical depression 6 in a plug element 7 closing one end of the tubular member 4. The plug element 7 is integral with the rest of the tubular member 4 but may also be a separate insert fitted into the tubular member 4.

Conductive leads 8 and 9 extend from the RTD 5 to soldered connection points 10 and 11 to conductive leads 12 and 13, respectively. The leads 12 and 13 extend through a cylindrical passage 14 in the tubular member 1 to the opposite end (not shown) thereof arranged outside the wall of the receptacle or conduit. The conductive leads 8, 9 and 12, 13 are enclosed in insulating and reinforcing sleeves 15.

A body 16 of heat conductive and electrically insulating ceramic cement fills the interior 17 of the tubular member 4 and envelops a stretch of each of the lead assemblies 8, 10, 12 15 and 9, 11, 13, 15. The RTD 5 is thus totally embedded in the body 16. The ceramic cement is constituted by OMEGA-BOND "600" ® manufactured by Omega Engineering Inc. Stamford, USA. The body 16 adheres to the walls of the interior 17 of the tubular member 4 thereby fixing the RTD 5 in position relative to said tubular member 4.

The plug element 7 is provided with an annular flange 18 with the same outer diameter as the tubular member 1. The flange 18 abuts the edge 3 and is circumferentially welded at 19 to the tubular member 1, thereby sealing the interior of the latter (passage 14) from contact with the fluid. The exterior diameter of the tubular member 4 is such relative to the diameter of passage 14 that a tight fit is established therebetween.

The edge region 20 of the open end of the tubular member 4 tapers towards a sharp edge, thereby providing a gradual transition from the tubular member 4 to the passage 14. This gradual transition is of importance for avoiding fatigue failure of the body 16 in this region due to vibrations to which the sensor is subjected.

The thickness of the plug element 7 in the axial direction determines the distance of the RTD 5 from the end surface 21 of the plug element 7 and thus the sensor itself. The rate of heat transmission to and from the RTD 5 from and to the fluid is to a great extent determined by said thickness, thereby indicating as small a thickness as possible so as to obtain as small reaction times as possible. However, as the execution of the weld 19 gives rise to a temperature above the design temperature of the RTD 5 in the close vicinity to the weld 19, the minimum thickness of the plug element 7 is determined by the necessity of protecting the RTD 5.

As will be appreciated, the RTD 5 may be positioned very precisely with respect to the axis of the tubular elements 1 and 4 and with respect to the end surface 21, thereby ensuring great uniformity from sensor to sensor as well as a very precise positioning of the sensor (RTD 5) with respect to the point where the temperature of the fluid is to be monitored. These factors represent a very great advantage compared to the known sensors where the position of the RTD is subject to a number of uncertainties.

The conductive leads 8, 9 and 12, 13 as well as the connection points 10, 11 are very well protected against fatigue failure by being embedded in the body 16 of ceramic cement, thereby avoiding a frequent cause of failure of the known sensors.

The position of the RTD 5 in physical contact with the plug element 7 having a substantial surface portion 21 in direct contact with the fluid is the main factor in achieving reaction times considerably shorter than with the known sensors (10-20% shorter when the fluid is a liquid and about 50% shorter when the fluid is a gas). Naturally this effect will also be achieved to a large extent even if the RTD 5 is only close to the plug element 7 and not in actual physical contact as the heat conductive cement will considerably reduce the heat transmission resistance across the gap.

The plug element 7 is constituted by commercial stainless steel but may naturally be made of materials with a higher heat transmission capacity if even shorter reaction times are required.

The tight fit between the tubular member 4 and the passage 14 is helpful in reducing the reaction time but does not appear to have anyway near the importance of the heat transmission path across the plug element 7.

In case the design temperature for the sensor is below 200°C the weld 19 may be replaced by a suitable sealing adhesive between the flange 18 and the edge 3 and in that case the thickness of the plug element 7 may be reduced, thereby shortening the reaction time. Above 200°C it has been found necessary to weld so as to ensure a long life for the sensor.

The fact that the diameter of the body 16 is substantially equal to the diameter of the passage 14 is of importance for the support of the conductive leads against fatigue failure.

Referring now to Fig. 2, a mould plate 30 having a series of bores 31 therethrough is used for the production of the resistance temperature detector assembly, 4, 5, 16, 8-15. The diameter of the bores 31 is substantially equal to the diameter of the passage 14 in the tubular member 1

Tubular members 4 are inserted from below in the bores 31. The RTDs 5 with leads 8 and 9 connected to the leads 12 and 13 and enveloped by the sleeves 15 are placed in the conical depressions 6 and the ceramic cement OMEGABOND "600" ® is injected into the bores 31 until they are substantially filled.

After the cement has hardened the detector assemblies are removed downwards out of the bores 31. The leads 12 and 13 are inserted in the aperture 2 of the tubular member 1 and are threaded through the passage 14 until reaching the not shown aperture at the opposite end of the member 1. The detector assembly is thereafter pulled through the aperture 2 into the passage 14 until the flange 18 abuts the edge 3 whereafter the weld 19 is carried out.

Although more elements are involved in the sensor according to the invention than in the known sensors the cost of production is considerably lower owing to the simpler and more controllable steps involved.

It will be appreciated that the positioning of the RTD 5 and the cement injection process according to the invention ensures that the necessary heat transmission will not be adversely affected by voids in the cement to incorrect positioning of the various elements relative to one another.

Although the present invention has been described in the foregoing in connection with a particular embodiment it will be understood by those skilled in the art that many changes and modifications may be carried out without departing from the scope of the invention as defined by the appended claims.

Thus the particular shape of the sensor casing and the detector casing may be adapted to various particular applications, the fixation material for the RTD and the leads may be chosen among all suitable materials and may also comprise suitable powder materials alone or in combination with suitable adhesive materials.

CLAIMS

1. A temperature sensor for use in monitoring the temperature in a fluid, the sensor comprising a sensor casing having a first and a second aperture mutually interconnected by a passage, a temperature detector assembly inserted in the first aperture, conductive leads electrically connected to the assembly and extending through the passage to the second aperture, the temperature detector assembly comprising a detector casing of a thermally conductive metal and a temperature detector, such as a resistance temperature detector or a thermocouple, accommodated in said detector casing, the assembly being arranged such in the first aperture that a substantial portion of the detector casing in use is exposed to direct contact with the fluid.

2. A temperature sensor according to claim 1, wherein the detector is at least partly embedded in a high temperature adhesive at least partly filling the detector casing.

3. A temperature sensor according to claim 2, wherein the adhesive is a heat conductive, electrically insulating ceramic cement.

4. A temperature sensor according to any of the claims 1-3, wherein the detector is in thermally conductive communication with a region of the detector casing comprised by or adjacent to said substantial portion thereof.

5. A temperature sensor according to claim 5, wherein the detector is in physical contact with a region of said substantial portion of the detector casing.

6. A temperature sensor according to any of the preceding claims, wherein the sensor casing comprises a first tubular member, having the first and second aperture, respectively, at opposed ends thereof.

7. A temperature sensor according to any of the preceding claims, wherein the detector casing compris a second tubular member having one end open and the other end closed by a plug element, at least a part of the plug element being at least a part of the substantial portion of the detector casing for exposure to direct contact with the fluid.

8. A temperature sensor according to claim 7, wherein the sensor casing and the detector casing comprise means for sealing the detector casing relative to the sensor casing such that the open end of the second tubular member in use is not exposed to the fluid.

9. A temperature sensor according to claim 8, wherein the plug element has an annular region with larger diameter than the diameter of the second tubular element such that an annular flange is formed around the closed end of the second tubular member.

10. A temperature sensor according to claim 9, wherein the outer diameter of the annular region of the plug element is substantially equal to the outer diameter of the first tubular member.

11. A temperature sensor according to claim 10, wherein the annular flange is welded to the first tubular member for establishing a fluid-tight seal therebetween.

12. A temperature sensor according to any of the claims 2-11, wherein the high temperature adhesive substantially fills the detector casing and envelops the first stretch of the conductive leads from the detector.

13. A temperature sensor according to claim 12 as dependent on any of the claims 7-11, wherein the edge region of the open end tapers to a substantially sharp edge.

14. A temperature sensor according to claim 12 or 13, wherein the adhesive enveloping said first stretch forms a cylindrical portion having the same outer diameter as the second tubular member.

15. A temperature sensor according to any of the claims 7-14, wherein the outer diameter of the second tubular member is substantially equal to the inner diameter of the first tubular member such that a tight fit may be established between the second and first tubular members.

16. A temperature sensor according to any of the claims 7-15, wherein the plug element comprises guiding means to guide the detector into a certain position relative to the plug element and maintaining means to maintain the detector in said position.

17. A temperature sensor according to claim 16, wherein the guiding means and maintaining means are constituted by a conical depression in the surface of the plug element facing the open end of the second tubular member, the conical depression receiving the detector adjacent the apex thereof.

18. A method of producing a temperature sensor for use in monitoring the temperature in a fluid, the method comprising the steps of

- providing a sensor casing having a first and a second aperture mutually interconnected by a passage,

- providing a temperature detector having conductive leads extending therefrom,

- providing a detector casing of a thermally conductive metal,

- locating the detector in a predetermined, fixed position within the detector casing by means of a heat conductive high temperature adhesive,

- inserting the conductive leads through the passage in the sensor casing from the second aperture thereof to the first aperture thereof,

- pulling the detector casing into the second aperture by means of the conductive leads to a sensing position such that a substantial portion of the detector casing is exposed to the exterior and thus in use will be exposed to direct contact with the fluid,

- fixing the detector casing in the sensing position, and

- sealing the detector casing relative to the sensor casing such that the passage, the detector and the conductive leads in use will not be exposed to the fluid.

19. A method of producing a temperature sensor for use in monitoring the temperature in a fluid, the method comprising the steps of:

- providing a first tubular member having a first and a second aperture at opposed ends thereof, the second aperture having an annular edge,

- providing a second tubular member having one end open and the other closed by a plug element having an annular region with a diameter substantially equal to the diameter of the first tubular element, said annular region forming an annular flange,

- providing a temperature detector having conductive leads extending therefrom,

- placing the detector in a predetermined position in physical contact with the surface of the plug element facing the open end of the second tubular member,

- providing a high temperature adhesive in the second tubular member such that the detector is fixed in said position,

- inserting the conductive leads through the first tubular member from the second aperture thereof to the first aperture thereof,

- pulling the detector casing into the second aperture by means of the conductive leads to a sensing position such that the annular flange abuts the annular edge of the second aperture,

- fixing and sealing the annular flange with respect to the annular edge such that the detector and the conductive leads in use will not be exposed to the fluid.

20. A method according to claim 19, wherein the adhesive is a heat conductive, electrically insulating ceramic cement.

21. A method according to claim 19 or 20, wherein the annular flange is welded to the annular edge for establishing a fluid-tight seal therebetween.

22. A method according to any of the claims 19-21, wherein the high temperature adhesive is provided such that it substantially fills the second tubular member and envelops the first stretch of the conductive leads from the detector.

23. A method according to claim 22, wherein the adhesive enveloping said first stretch is provided such that it forms a cylindrical portion having the same outer diameter as the second tubular member.

Fig. 1

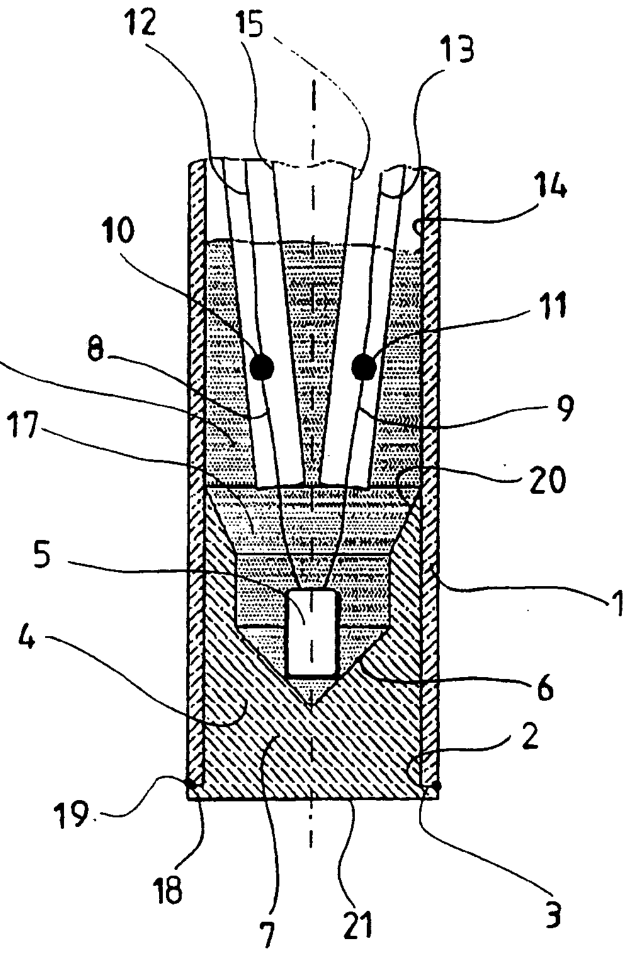
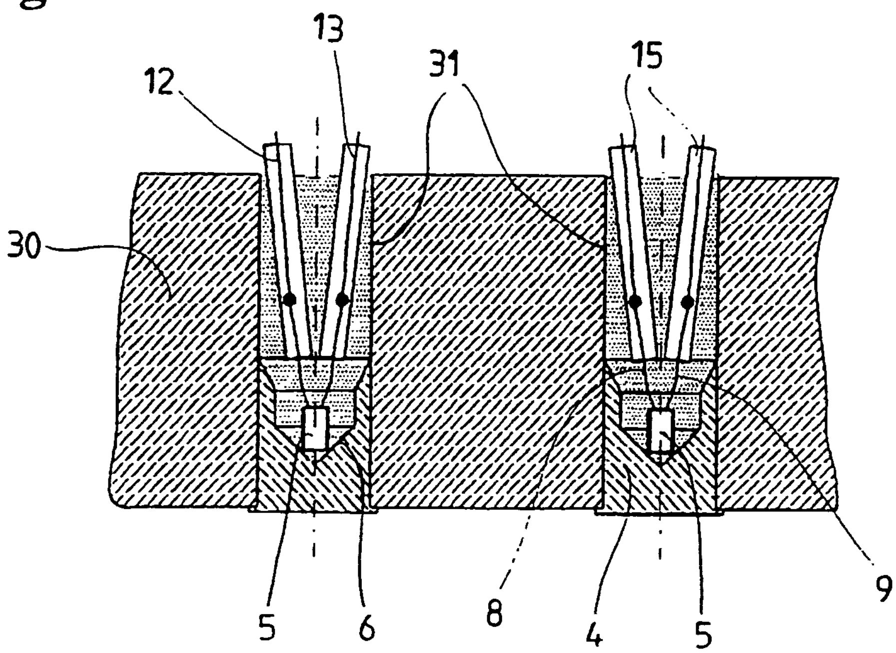


Fig. 2



INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/DK 96/00281

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01K1/16 G01K13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,30 37 449 (RABE HANS JUERGEN) 19 May 1982 see page 4; figure 1 ---	1,8,9, 15-17
A	DE,A,14 73 298 (METRAWATT AG) 27 March 1969 see the whole document ---	1,8,9, 14,15
A	DE,B,11 52 834 (HERMANN REBER) 14 August 1963 see the whole document ---	1,3,10, 11,14
A	DE,A,14 73 254 (DEUTSCHE GOLD UND SILBER-SCHEIDEANSTALT) 5 December 1968 see the whole document ---	1,15
A	DE,A,19 27 147 (MBB) 3 December 1970 see page 5 - page 6; figures -----	18

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1

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 1996	16.10.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Ramboer, P

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
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DE-A-1473298	27-03-69	NONE		
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